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Research Note

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MINERAL CONTENT AND PYROLYSIS OF SELECTED PLANT MATERIALS

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ABSTRACT

Recent studies of pyrolysis of plant materials indicate that the rate of thermal degradation and the amount of volatile materials formed are directly related to the silica-free ash content (SFA) of the material. However, plants with SFA above 12 percent that were tested did not fit these relationships. Evidence was found that only certain constituents of SFA are effective in inhibiting pyrolysis.

Recent work on pyrolysis of cellulose contaminated with inorganic compounds has led to the conclusion that the flammability of plant material is influenced by the presence of inorganic materials (6).[3] Broido and Nelson (1) found that naturally dried and leached corn leaves were more flammable than unleached leaves because of differences in inorganic composition. Tamarix species was found to be fire resistant, presumably due to its extremely high mineral content (7). Since the mineral content of growing plants could drastically influence their combustibility, there is a possibility that "fire resistant" plants may be cultivated for specific geographic locations (4). Also, the chemical composition of different fuels may be quite important in predicting their flammability and should therefore be included in fuel evaluation systems.

Cellulose, the major component of plant material, apparently pyrolyzes by at least two different pathways. At low temperatures thermal decomposition provides CO, CO_2, H_2O and a charred residue that supports glowing combustion (4). At high temperatures, degradation of the macromolecules gives a large variety of low-molecular-weight organic compounds that support the flaming combustion (5). Treatment of cellulose with

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[3]Numbers in parentheses refer to Literature Cited.

inorganic flame retardants, such as $(NH_4)_2HPO_4$, $ZnCl_2$, and $KHCO_3$, increases the char formation at the expense of the flammable, volatile compounds. Minerals present in plants have the same effect. On this basis, hazard rating of natural fuels and selection of more fire resistant plants should include consideration of chemical composition as well as physical properties. Several plant species are being studied for this purpose.[4] In the present study, several plant materials with ash contents ranging from 0.11 to over 27 percent were investigated by thermogravimetric analysis (TGA). A variety of species was used to get a broad range of mineral contents, not to assess the fire characteristics of the species itself.

The plant materials tested were:

"Ash-free" cellulose, 1[5]

Wood: Pseudotsuga menziesii, 2

Betula sp., 3

Pinus ponderosa, 4

Populus sp., 5

Grass: Bromus tectorum, 6

Elymus caput-medusae, 7

Needles: Pinus ponderosa, 8

Pinus monticola, 10

Twigs: Adenostoma fasciculatum, 9

Leaves: Adenostoma fasciculatum, 11

Populus tremuloides, 12

Psidium guajava, 13, 14, 15

Atriplex canescens, 16

Tamarix aphylla, 17

Atriplex polycarpa, 18

Atriplex lentiformis var. brewerii, 19

Atriplex nuttallii var. gardnerii, 20

Atriplex gardnerii, 21

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[4]Work being done at U.S.D.A. Forest Service, Forest Fire Laboratory, Riverside, California.

[5]Numbers refer to those used in figure 1.

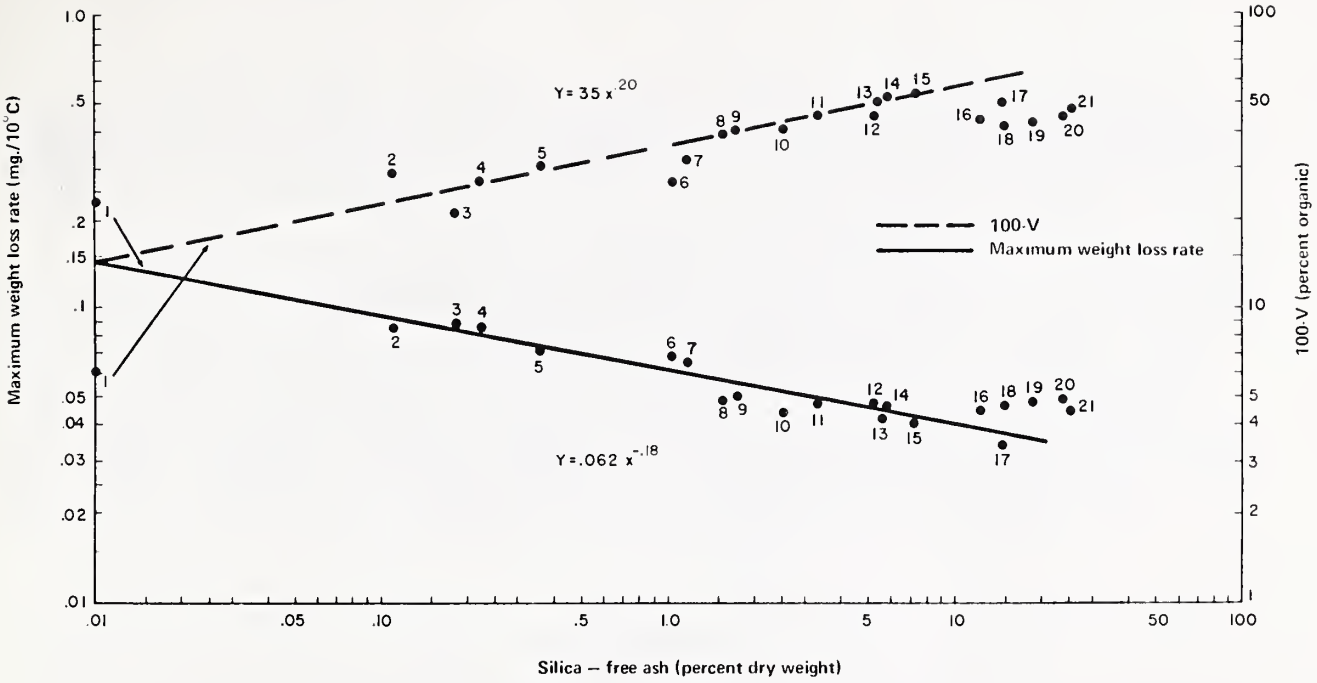

Figure 1.--The relationships between maximum weight loss rate and 100-V, and SiO_2-free ash.

The plant material was dried, ground to pass 40 mesh and be retained by 60 mesh, and analyzed for total ash and silica content.[6] The total Ca, Na, and K was determined by flame photometry and P and Fe were determined by colorimetry. All chemical analyses except for SiO_2 were performed after wet digestion with a ternary acid mixture. Ten-mg samples were used in a DuPont[7] model 950 thermoanalyzer in a stream of N_2 at 100 cc./min. and a heating rate of 15°C./min. All experiments were set electronically to record percent weight loss after the moisture was driven off. Three replications were made on each species.

Following the lead of Browne and Tang (2), differences in the pyrolytic reactions and reaction products were judged according to two criteria: maximum weight loss rate during active pyrolysis and total weight loss during pyrolysis from 175° to 350°C., or V, when expressed as a percentage of original organic matter present. Active pyrolysis of these fuels ceased at 350°C., above which only very small weight loss occurred. All weight is expressed as percent of original organic matter.

The results shown in figure 1 indicate that for these samples the rate of pyrolysis is inversely related to silica-free ash content up to 12 percent (dry weight). The SiO_2 content has been deducted from the ash because it has been shown to have little, if any, effect upon pyrolysis.[8] A direct relationship holds for 100-V when V is the

[6]ASTM Standards, D1102-56, Methods of test for ash in wood. Assoc. Offic. Agr. Chem., Methods for Analysis, 6.005. 1965.

[7]Use of trade names herein is for identification and does not imply endorsement by the U.S.D.A. Forest Service.

[8]Mutch, R. W., and C. W. Philpot. High ash content: not always equated with low flammability. Intermountain Forest and Range Exp. Sta. (In preparation.)

weight lost by the organic materials from 175° to 350°C. The plants that show the largest deviation are all of the genus Atriplex. These plants have been suggested as being fire resistant due to high mineral content. Tamarix showed the lowest maximum weight loss rate, which further substantiates the work of Waisel and Friedman (7).

The mineral analysis showed that Na content of the Atriplex tested ranges from 0.18 to 8.46 percent, and the K content ranges from 1.03 to 4.68 percent. For example, A. gardnerii, 21, has 8.46 percent Na as compared to the 0.1 percent or less for the other genera and 28 times that of Tamarix. A. canescens, 16, has a K content of 4.68 percent or eight times that of Tamarix. The P content of the Atriplex ranges from 0.185 to 0.307 percent. The P content of Tamarix is 0.150 percent. This suggests that K and Ca have less effect on pyrolysis than does P. Despite higher silica-free ash content, Atriplex does not show any pyrolytic advantage over Tamarix as indicated by TGA data. Thus all ash constituents are not equally effective and total ash content should not be used to rate relative pyrolytic characteristics of natural fuels.

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